Countryside Stewardship organic management and conversion options: A scoping study to establish a monitoring protocol: Methods, power analysis and costing

07/07/2020

Peter Carey, Mary Dimambro, Francis Rayns

Contact: Dr.P.D.Carey, Bodsey Ecology Limited

Executive summary

Approximately £3 billion will be invested in agri-environment schemes (AES) through the 2014-2020 Rural Development Programme for England (RDPE). Of this, around £900m will be for the Countryside Stewardship (CS) Scheme, within which approximately £12m is specifically allocated to supporting organic farming (approximately 1.3%).

The key objective of this project is to recommend a methodology to test a list of key questions agreed at the end of the first stage of this project as follows:

1. How do the biodiversity elements measured for organic maintenance options compare to similar land not in Countryside Stewardship (CS)?
2. How do the biodiversity elements measured for the conventional options in CS compare to organic maintenance options?
3. How does biodiversity on the maintenance options of CS compare to the biodiversity of conventional farms with similar environmental settings and/or farm business types?
4. Do the biodiversity elements measured for conventional options change at a different rate to conventional farms in CS as farms convert to organic production?
5. How does biodiversity change as a farm converts to organic production compared to a similar farm that is outside of CS over the same time period?
6. How does soil organic matter differ between conventional farms and organic farms in CS?
7. Is there a difference in soil erosion between conventional and organic farms in CS?
8. How do soil biota differ between conventional and organic farms in CS?
9. Is there a difference in water quality leaving conventional and organic farms in CS?
10. Do organic farms maintain or change the landscape in a way different from conventional farms in CS?
11. Can the public benefits of organic and conventional farms in CS be quantified and compared: what are the variables (above and beyond those in question 1 to 9) that need to be collected to do this?

The project Steering Group and Project Team decided that it would be most appropriate to focus on the biodiversity elements measured in past agri-environment monitoring and especially the Project LM0458. For soil organic matter and erosion, water quality, landscape character and public benefits less effort has been spent in past agri-environment scheme monitoring and there are developing methodologies that could be applied.

A key question for all studies is how robust should the results be statistically. *A priori* power tests for ANOVA, χ^2 and t-test are provided as tables (Appendix 1) that can be used to determine the sample size required to achieve statistical significance at <0.05 probability for a range of sizes of effect and power. An alternative view is to use a case-study approach where statistical significance is not the goal but in depth analysis of a small number of farms gives descriptive text that provides evidence. Evidence from previous studies, as identified in the literature review for this project will be a key component key to the case-study approach.

The ultimate decision to be made is how much can be achieved with the resources available. A table of costs per method per sample is provided. A final output in addition to the agreed reports and recommendations of this project is an Excel workbook that allows the customer to select the

elements to include, choose the level of power required and the effect size that will be detected to give the sample size and then determine the cost of a project.

Table of Contents

1 Introduction

In 2017, the United Kingdom had a total area of 517 thousand hectares of land farmed organically (i.e. the fully converted area and area under conversion), (Defra, 2018). Permanent pasture accounts for the biggest share of the organic area (64%) followed by temporary pasture (18%) and cereals (7%).

Approximately £3 billion will be invested in agri-environment schemes (AES) through the 2014-2020 Rural Development Programme for England (RDPE). Of this, around £900m will be for the Countryside Stewardship (CS) Scheme, within which approximately £12m is specifically allocated to supporting organic farming (approximately 1.3%). The remaining £2.1 billion of the RDPE budget is allocated to legacy schemes such as Environmental Stewardship.

Prior to 2015, there were three main environmental schemes in England, being Environmental Stewardship, Catchment Sensitive Farming and the Woodland Grant Scheme. These were combined, in 2015, into CS as one of the main mechanisms for delivery of Defra's Strategic Objective of 'a cleaner, healthier environment, benefiting people and the economy'. CS also contributes to the Defra Single Departmental Plan and should help to address the new 25 year Environment Plan[1]. The five main scheme objectives are:

- Biodiversity
- Resource protection
- Historic environment
- Landscape
- Climate change adaptation

Other CS outcomes include:

- flood and coastal risk management
- landscape character
- genetic conservation

CS (and the earlier schemes) provides support for the management and conversion to organic practices, as a means of delivering the scheme objectives as well as supporting the European Action Plan for Organic Food and Farming. The specific contribution of Organic Management and Conversion options in AES has yet to be systematically monitored and evaluated in England at a national scale, to determine whether the environmental impact of organic management under AES is in line with research data from the UK and across northern Europe and other climatically similar regions worldwide. It is important that this is understood fully because the UK has circa 517,000 ha of land in organic farming, is the 16th largest globally, with organic farming representing 2.9% of agricultural land (Willer & Lernoud, 2016).

The focus of this project is the organic management and options within CS, as listed below.

Management options
OT1: Organic land management - improved permanent grassland
OT2: Organic land management - unimproved permanent grassland
OT3: Organic land management - rotational land
OT4: Organic land management - horticulture
OT5: Organic land management - top fruit

[1] https://www.gov.uk/government/publications/25-year-environment-plan accessed 19/12/2018

OT6: Organic land management - enclosed rough grazing

Conversion options
OR1: Organic conversion – improved permanent grassland
OR2: Organic conversion – unimproved permanent grassland
OR3: Organic conversion – rotational land
OR4: Organic conversion - horticulture
OR5: Organic conversion - top fruit

The monitoring of organic arable options is already included within the CS baseline project ECM47452[2]
OP1: Overwintered stubble
OP2: Wild bird seed mixture
OP3: Supplementary feeding for farmland birds
OP4: Multi species ley
OP5: Undersown cereal

These organic management and conversion options need to be considered in relation to land in conventional agriculture and, where appropriate, the equivalent? management options for farms in CS with conventional agricultural management.

The CS guidance notes and manual for the various organic options state that there will be a maintenance or increase in environmental and public benefits from an agreement with that option. For example, OT5 – Organic land management top fruit reads: "Maintains top fruit orchards under organic management, providing a range of environmental and public benefits." However, there is no further information on what those benefits might be.

Many of the desirable goals of reducing the intensity of farming practices such as: increased soil organic matter (SOM), resulting in better soil structure; reduced erosion; and better water infiltration as water holding capacity is increased, are likely to occur on organic farms but not exclusively. This is also true for the use of nitrogen fertilisers and other inputs, although the removal of herbicides, insecticides and fungicides rather than reducing their use (as in Integrated Farm Management[3]) should theoretically be more beneficial on organic farms. With a reduction of agrochemical inputs it has been assumed organic production will be beneficial to biodiversity in comparison to conventional farming. There has been a large body of research to investigate the potential benefits of organic farming and then subsequent meta-analyses to summarise the research as shown in the literature review for this project. This document provides suggested methodological protocols for different elements (e.g. birds) that might be chosen by Natural England and Defra for the monitoring and evaluation of CS organic options. A power analysis gives approximate sample sizes required to detect differences statistically. The cost of a survey based on the elements chosen and the sample size can be calculated using an Excel workbook provided as an output of this project. Ultimately the scope

[2] The Environmental Effectiveness of the Countryside Stewardship scheme; Establishing a Baseline Agreement Monitoring Sample (LM0458).
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=19728&FromSearch=Y&Publisher=1&SearchText=lm0458&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[3] "**Integrated Farm Management** (IFM) is a site-specific **farm** business approach that uses the best of modern technology and traditional methods. Attention to detail is key; appropriate and efficient use of inputs, smarter approaches to business planning and the adoption of innovations and new technologies, all contribute to increasing productivity whilst protecting valuable resources." LEAFUK.org

and size of the monitoring project will depend on the available funds and this cannot be factored in at this stage.

2 Project objectives

Objective 1. Review the literature base to confirm the specific monitoring questions to be tested in relation to the environmental impact of organic conversion and management AES options.

Objective 2. Identify any useable, existing monitoring data, (for example from past agri-environment monitoring databases or from other sources such as Universities, Organic Farming bodies and private individuals), suitable for use as a baseline against which to compare future monitoring.

Objective 3. Recommend a methodology to test the monitoring questions. This should include an assessment of alternative methodologies and a justification for the recommendation given.

3 Contextualising the questions to be answered by the Monitoring and Evaluation

In this section the questions that are to be answered by the monitoring and evaluation programme are listed. The questions were agreed by the project Steering Group and the Project Team at the end of the first stage of this project.

3.1 The Questions

1. How do the biodiversity elements measured for organic maintenance options compare to similar land not in Countryside Stewardship (CS)?
2. How do the biodiversity elements measured for the conventional options in CS compare to organic maintenance options?
3. How does biodiversity on the maintenance options of CS compare to the biodiversity of conventional farms with similar environmental settings and/or farm business types?
4. Do the biodiversity elements measured for conventional options change at a different rate to conventional farms in CS as farms convert to organic production?
5. How does biodiversity change as a farm converts to organic production compared to a similar farm that is outside of CS over the same time period?
6. How does soil organic matter differ between conventional farms and organic farms in CS?
7. Is there a difference in soil erosion between conventional and organic farms in CS?
8. How do soil biota differ between conventional and organic farms in CS?
9. Is there a difference in water quality leaving conventional and organic farms in CS?
10. Do organic farms maintain or change the landscape in a way different from conventional farms in CS?
11. Can the public benefits of organic and conventional farms in CS be quantified and compared: what are the variables (above and beyond those in question 1 to 9) that need to be collected to do this and how often do they need to be collected?
12. Is a baseline and a comparison at the end of CS agreement sufficient?

4 Measuring Biodiversity (Questions 1 to 5)

Countryside Stewardship aims to reverse the declines in farmland biodiversity (as demonstrated by the farmland biodiversity indicators[4]). No previous monitoring and evaluation project of an agri-

[4] UK Biodiversity Indicators: Updated 19 July 2018 accessed at http://jncc.defra.gov.uk/page-4229 14/12/2018

environment scheme has monitored biodiversity that is directly related to the biodiversity indicators, which is partly because the indicators have been updated recently.

The Steering Group for this project decided that it would be most appropriate to focus on the biodiversity elements measured in past agri-environment monitoring and especially The Environmental Effectiveness of the Countryside Stewardship Scheme - Establishing a baseline agreement monitoring sample: Natural England Contract LM0458[2] (CS Baseline Monitoring Project). Any linkages that could be made to the national indicators for farmland biodiversity: farmland birds, butterflies and bats, in addition to farmland plant species richness (discontinued because Countryside Survey 2007[5] is now out of date) would be welcomed. There is also a national indicator for pollinating insects (bees and hoverflies) that provide a vital ecosystem service for food production. It was considered that linking to pan-European monitoring schemes such as BioBio[6] would be desirable rather than preferable.

Biodiversity has been measured throughout the development of agri-environment schemes from the early 1990s onwards. There are no studies where the same elements of biodiversity have been collected and there is therefore not a 'standard set' to work from (Table 1). In the following sections methodologies for collecting data on the variables comparable with and the previous studies in Table 1 and UK Biodiversity indicators are outlined. There have been some recent methodological developments and these are suggested as the appropriate method for the future evaluation of organic options of Countryside Stewardship if they provide a significant advance in quality or a cost saving.

All of the following elements (apart from habitat mapping) should be recorded a minimum of twice for organic conversion farms, once as a baseline and once after five years. To show change all farms should be surveyed twice but if the goal is to compare with conventional options then the sampling should be carried out at the same frequency for both conventional and organic farms.

4.1 Habitat Mapping

Habitat maps may be required to produce figures to compare the area of habitats of different types between organic and conventionally farmed land. They are also required for assessing connectivity and landscape character. Habitat mapping is most relevant to permanent pasture, linear features (hedges, ditches etc.) and points of interest (e.g. veteran trees), rather than temporary CS land management options such as winter bird seed mix or pollen and nectar mix. The use of high quality images taken from drones is revolutionising the accuracy with which habitats can be mapped. There is still a need for ground-truthing when surveying a new area (e.g. hand held GPS) so that the drone images can be interpreted. Although the authors of this report do not have experience in the use of drones, we understand that with the correct licence they are relatively easy to employ (by an experienced flyer). Habitat maps provide not only an inventory of the area and quality (in terms of designation) for the habitats present but are hugely important when calculationg ecosystem service delivery and potential and for creating the landscape context for many species such as birds that are considered beneficiaries of organic farming. Habitat mapping has only been carried out for Annex I habitats and Habitats of Principal Importance in the CS baseline project especially where these are found on Sites of Special Scientific Interest and we would recommend extending this to all areas visited. Remote sensed data products such as those from the new National Living Maps project could be considered as a more cost effective and provide a nationally standardised solution.

---

[5] Carey, P.D. , Wallis, S.M., Emmett, B.E., Maskell, L., Murphy, J., Norton, L., Simpson, I., Smart, S.M. (*2008*). *Countryside Survey 2007: UK Main Report,* NERC, Swindon, pp 150.

[6] http://www.biobio-indicator.org/project.php accessed on 19/12/2018

The UK Habitat Classification (UKHab)[7] should be considered for mapping polygons (fine scale minimum mapping unit at >25m^2, coarse scale minimum mapping unit at >400m^2), linear features and points (for features smaller than the minimum mapping unit) in preference to earlier systems because it has direct translation to EUNIS and to all common habitats as well as Habitats of Principal Importance and, Annex I habitat types. UKHab also has a dedicated set of codes that indicate management, moisture and other features such as scattered rushes or bracken. In addition the General Habitat Codes (GHC) from the European wide BioHab[8] project could be added to provide consistency if that system is adopted across Europe.

4.2 Vegetation

The methods for assessing vegetation quality are now standardised and require relevant botanical expertise, especially for rare arable weeds and for non-native species within sown mixes. The UK

[7] ecountability.co.uk/ukhabworkinggroup-ukhab/ accessed on 21/12/2018
[8] https://cordis.europa.eu/project/rcn/67639/factsheet/en accessed on 21/12/2018

Table 1. Biodiversity Elements Recorded by Current and Past Evaluation Protocols

Evaluation Protocol	Option in Place	Birds	Habitats	Vegetation	Flower abundance	Seed abundance	Bats	Bees	Butterflies	Spiders	Carabids	Other Arthropods	Earthworms	Soil Biota (genomics)
CS Baseline	yes		BEHTA (Higher tier) + landscape features	yes	yes	yes				yes - small sample	yes - small sample	yes - small sample		yes - small sample
BioBio			General Habitat Codes codes + landscape features	yes				yes		yes			yes	
CEH (Pywell/ Heard)	yes		yes	yes	yes			yes	yes	yes	yes	yes	yes	yes
CFE (FERA)	yes			yes	yes	yes								
Farmer Attitudes (FERA)	yes		landscape features	yes										
OF0165 (BTO/CEH-Norton)		Wintering	Landcover Map 2000 + quality metrics	yes			yes			yes	yes			

Biodiversity indicator will be adopting the National Plant Monitoring Scheme (NPMS)[9] results for 400 indicator species using presence in 5 x 5 m plots (10 x 10m in woodland) and 25 x 1 m linear plots (including arable margins). It would seem logical to use these plot sizes when recording on farmland, if CS is to be compared to the new indicator. However, detailed monitoring of abundance should be carried in a smaller sub-plot nested within the larger plot (1 x 1 m which are comparable with many legacy datasets including Countryside Survey and ESA monitoring or 0.5 x 0.5m which are comparable with the CS Baseline Monitoring Project). A suggested frequency for the sub-plots (following on from the CS Baseline project for biodiversity assessments) would be ten quadrats per option, or 20 if it is a SSSI, in a W across the area.

There are a range of measurements that can provide robust indicators of vegetation quality for common non-priority grasslands, CS arable options and potentially also for the organic conversion and maintenance options for arable and grassland fields, that can be easily collected from the sub-plots. They include grass:herb ratio; sward height; presence of injurious weeds; % bare ground; % litter; number of flowers; a measure of seed abundance. These measurements, most of which are collected in the CS Baseline Monitoring Project, are related to habitat quality for plant species and animals rather than a direct indicator.

The measurement of hedgerows (woody linear features) should follow BEHTA handbook protocols (as carried out in the CS Baseline Monitoring Project, with five vertical quadrats per hedgerow, but including the species recorded not just the number of species[10]), although a Countryside Survey hedgerow assessment would give the same and extra valuable information for little extra effort[11].

4.3 Birds

Having a measure of bird species present and their abundance is very important because of the links to the UK biodiversity indicators. The CS Baseline Monitoring Project and studies such as the project to assess the Campaign for the Farmed Environment have assessed the flower and seed resources provided by pollen and nectar strips and have assumed that this will increase the number of birds (based on research from the Game and Wildlife Conservation Trust). We believe a direct measure of bird abundance is preferable. However, bird surveying is time consuming and can be expensive if undertaken by skilled professionals. The abundance of 19 species (Table 2) of farmland birds is used to calculate the UK farmland bird indicator. Self-assessment by the farmers, their families or local naturalists for these recognisable common species may be the only cost-effective way of achieving data collection. The abundance of birds will be linked to the landscape in which the surveyed option/farm sits. To make a full assessment the bird data would need to be connected to habitat maps as described in Section 4.1 above. If direct measurement of bird abundance is not feasible, an assessment of flower and seed resources (via biodiversity assessments) and invertebrates would

---

[9] Walker, K.J. et al. 2015. Making Plants Count. British Wildlife, 26(4): 243-250

[10] The Environmental Effectiveness of the Countryside Stewardship scheme Establishing a baseline agreement monitoring sample Natural England Contract Reference ECM47452/22965 Draft Field Surveyor Handbook V4 May 2017 p31-32

[11] Maskell, L.C., Norton, L.R., Smart, S.M., Carey, P.D., Murphy, J., Chamberlain, P.M., Wood, C.M., Bunce, R.G.H. and Barr, C.J. (2008). CS Technical Report No.1/07 Field Mapping Handbook. Centre for Ecology and Hydrology (Natural Environment Research Council), pp114-119 accessed at http://nora.nerc.ac.uk/id/eprint/5194/1/N005194CR.pdf 14/12/2018

provide predictive data of available food resources (as in the previous projects mentioned above) although this could always be criticised because it does not prove impact on bird populations at all.

Table 2. List of species included in the UK Farmland Bird Indicator

Species included in the UK Farmland bird indicator		
Corn Bunting	Linnet	Tree Sparrow
Goldfinch	Reed Bunting	Turtle Dove
Greenfinch	Rook	Whitethroat
Grey Partridge	Skylark	Wood Pigeon
Jackdaw	Starling	Yellowhammer
Kestrel	Stock Dove	Yellow Wagtail
Lapwing		

4.4 Bats

Nine species of bats are monitored in the National Bat Monitoring Programme (NBMP)[12] using a number of volunteer led surveys of roosts and feeding areas. Landowners could be asked to do this with bat detectors provided to them. The method is time consuming and at anti-social times and uptake would likely be small.

Bat surveying is now common place amongst ecological consultants because of the requirements under the Habitats and Species Regulations 2017. However, it is fairly expensive to do (properly) as it requires staff to visit for several nights in a row. Purchasing a set of equipment as used by the BTO in the Norfolk Bat Survey[13] (about £500 for all equipment necessary) and placing it on sample farms for a few days would probably yield very good results at lower cost than sending surveyors out every evening for a week. There is an additional cost in analysing the resultant data.

4.5 Bees

Bee transects have been carried out by a number of groups (most notably CEH). However, CEH tend to have a small sample of intensively monitored case-study farms. Although the method is straightforward, it does require repeat visits through the summer and is weather dependent. The dependence on weather means that planning farm visits in advance is virtually impossible and logistically requires the surveyors to live very close to the sample farms. A “beewalk” transect following the methods of the Bumble Bee Conservation Trust[14] would seem the most appropriate monitoring method and as for birds, farmer self-assessment may be the most cost-effective method of survey. The surveyor or farmer would need to be capable of identifying potential bee species. This transect technique could also include recording other pollinators.

4.6 Butterflies (and macro-moths)

The Butterfly Monitoring Scheme (BMS)[15] has a rigid protocol which could be utilised by a trained surveyor, but is probably too rigorous for all but the keenest farmer. Noting numbers of common butterflies seen on a BeeWalk transect will provide useful information even if it is a simple as

---

[12] National Bat Monitoring Programme: Field Surveys. Bat Conservation Trust accessed at https://nbmp.bats.org.uk/Surveys.aspx 14/12/2018

[13] E.g. Songmeter SM4Bat-ZC Bat Recorder from Wildlife Acoustics although others are available

[14] Comont, R. F. & Dickinson, H. 2018. BeeWalk Annual Report 2018. Bumblebee Conservation Trust, Stirling, Scotland UK, pp18-19

[15] Methods for Recording Butterfly Transects. Butterfly Monitoring Scheme accesses at http://www.ukbms.org/Methods on 14/12/2018.

‘Brown’, ‘Blue’, ‘Tortoiseshell’, ‘Peacock’, ‘White’ although these data would not be directly comparable with BMS, and as with the bee transects will be weather dependent.

4.7 Spiders and other above ground arthropods

Arthropods have often been used as indicators of biodiversity in studies of farmland management and agri-environment schemes across Europe and are included in the BioBio protocols but are not a UK Biodiversity Indicator.

Many studies have used pitfall traps to collect ground dwelling arthropods, with malaise traps and occasionally pan traps to collect flying arthropods and they have been shown to be very important indicators of biodiversity and ecosystem health. These methods require time to install the traps plus at least one return visit and are prone to failure if not properly set-up and maintained. With the exception of flooding due to excessive rainfall, these traps are less sensitive to the weather than undertaking transect walks. The number of replicates put out in the field must be large enough to deal with losses (e.g. ten for pitfall traps). A single Malaise trap per site may be sufficient but may need repeating if destroyed by bad weather the first time. CEH and Rothamsted have used ‘D-Vac’ vacuum collectors for above ground dwelling arthropods; this is a very efficient method and, once the equipment is bought, relatively cost effective. The cost of sorting and identifying the caught spiders and insects is very time consuming and hence expensive. Using genomic techniques may be cheaper than identification but not necessarily.

4.8 Earthworms

For the comparison of organic and conventional farms an indication of earthworm abundance and diversity will be one of the most important variables because of the potential influence of the range of management practices including minimum tillage and pesticide use versus ploughing and non-pesticide use, plus other factors such as the use of cover crops and manures. Earthworm sampling using the standard recording protocol (25 x25 cm, 10cm deep) of the National Earthworm Recording Scheme (NERS)[16] is recommended. The collected soil needs to be processed quickly and therefore a dedicated team of worm collectors and sorters will be required if field surveyors have other tasks.

5 Measuring Soil Properties

As soil health is such a key aspect of organic farming we consider that an adequate amount of resources should be spent on gathering useful information.

The cheapest alternative is the spade test which can be used with a score sheet[17]. The Great Solis Project identified a range of measures of soil quality[18]

The soil related variables currently collected for the CS baseline project have designed to assess soil texture and chemical properties. Fifteen bulked soil cores are collected to a depth of 15 cm in a ‘W’ pattern across the sampling area. Soil texture (% sand, silt and clay; laser method); pH (in water); Olsen extractable phosphorus (P); Ammonium nitrate extractable potassium (K) and magnesium (Mg); Total nitrogen (N); Total organic matter based on dry combustion (loss-on-ignition - LOI); and Organic carbon by the Dumas method are all carried out by laboratory analysis. Soil physical assessments include topsoil bulk density (0-15 cm – at 5 locations in the sampling area); and visual soil evaluation of soil structure using the Visual Evaluation of Soil Structure (VESS; Guimaraes *et al.*, 2011) and Visual Soil Assessment (VSA; Shepherd, 2000) methods (at three locations randomly selected within the sampling area).

---

[16] Brown,K.D. (2017). *Earthworm Recorder’s Handbook of the National Eartworm Recording Scheme*. Earthworm Society of Britain Accessed at http://www.earthwormsoc.org.uk/sites/default/files/2017-10/Earthworm%20Recorder%27s%20Handbook.pdf 14/12/2018

[17] https://www.sruc.ac.uk/info/120625/visual_evaluation_of_soil_structure

[18] https://www.soilassociation.org/media/8179/martinwood.pdf

Countryside Survey[19] collected soil samples from which: pH; soil organic matter (SOM); soil organic carbon (SOC); bulk density; soil texture (hand analysis method); total-N; soil C:N (by calculation); Olsen-P; potential mineralisable N were analysed. Some or all of these variables could be determined for the assessment of the organic options of CS and compared to the national statistics provided by Countryside Survey. The collection method for Countryside Survey uses four lengths of cut drain pipe of different lengths and diameters to collect samples for different variables. The collection method is designed so that the samples can be posted immediately back to the laboratory which is vital for consistency. An alternative would be to use a standard auger with samples being collected by a commercial laboratory service.
Note that soil analysis laboratories produce consistent results from samples that they process but there is not consistency between laboratories and so all samples from a project (or related projects) should be analysed by the same laboratory/company.

6 Measuring Soil Erosion

The CS baseline project uses a range of techniques to assess the likelihood of soil erosion, and hence the potential for the CS option to reduce erosion, including soil type (texture analysis), % cover (total and vegetation >3cm tall), option location and slope above the option. This provides basic data which are collected when the surveyor is also assessing other factors such as vegetation, and should also be included in the organic methodology.

The Environment Agency have been developing a GIS solution to predicting which fields in a catchment are likely to be prone to soil erosion using a combination of Sentinel satellite data and Lidar digital terrain models. The EA models could be used to identify which fields in farms in the sample are at risk from erosion. These fields could be visited shortly after heavy rainfall/storms to assess whether they are actually being eroded. Obvious signs of erosion, like gullies could be recorded during field walks. This would require the ability of the survey team to react quickly following a storm event, most probably in the winter. Sentinel data could be used to detect colouration in rivers but only in areas where there are large water courses and/or the watercourses are not shaded.

There are no longer soil erosion monitoring programmes in operation in England and in any case they could not identify which individual fields were responsible for the sediments in the river.

There are conventional CS options to protect soil and also CS organic options to protect soil. It would be instructive to compare these two sets of options directly. This may give an indication of any inherent differences between organic and conventional systems with respect to soil erosion. The null hypothesis that there is no difference between the two systems would be tested.

7 Measuring Soil Biota

Apart from earthworms other soil invertebrates can be measured from soil samples collected using plastic pipes that are then processed quickly. We recommend a sample of similar size to Countryside Survey (8cm x 4cm diameter pipe – designed to fit in a post box). The invertebrates were extracted

[19] Emmett, B.A., Reynolds, B., Chamberlain, P.M., Rowe, E., Spurgeon, D., Brittain, S.A., Frogbrook, Z., Hughes, S., Lawlor, A.J., Poskitt, J., Potter, E., Robinson, D.A., Scott, A., Wood, C., Woods, C. (2010). *Soils Report from 2007: CS Technical Report 9/07.* Centre for Ecology and Hydrology, Wallingford. Accessed at https://countrysidesurvey.org.uk/content/soils-report-2007 14/12/2018.

from the samples using Tullgren funnels. There is a large cost involved in extracting, sorting and identifying the invertebrates.
An alternative method is to use genomics, which will also detect the biodiversity of microbial organisms and fungi. The Countryside Survey protocol involved using 15cm long x 4cm diameter pipes to collect material. The material would then be analysed in a laboratory using DNA meta-barcoding (e.g. by FERA, CEH, University of Reading, NatureMetrics) to compare soil functionality between fields in the sample.

During the CS Baseline project invertebrates were extracted from soil cores using Tullgren funnels and combined these with the invertebrates from pitfall traps and malaise traps. It is unclear whether soil microbial diversity was measured from the soil cores. We suggest the errors and failure rates associated with pitfall traps and malaise traps make combining the data collected from these traps with data from soil cores unnecessarily inaccurate. It would be better to keep the above ground invertebrate sampling separate from the soil diversity sampling.

8 Measuring Water Quality

Water quality as it leaves the farm is an important measure of the success of agri-environment schemes generally, irrespective of the requirements under the Water Framework Directive. The monitoring stations of the water companies and the Environment Agency along major waterways provide contextual information but these do not relate to the output from individual fields. Surface water quality can be measured directly from ditches, streams and rivers but this requires an initial assessment of which water bodies will be relevant to the farm followed by regular monitoring over-time. Porous cups installed within fields that are checked fortnightly can also be used to measure water flow downwards and are often used to assess nitrate leaching. Water quality can be measured indirectly using indicator plant and invertebrates within the relevant water bodies (RICT/RIVPACS[20]). The impact on ground water over long periods of time might be possible but we assume here that the time-scale is too long to provide useful information.

9 Evaluating the Landscape

The connectivity of the landscape is a key indicator in the England Biodiversity Indicators as measured by the functional connectivity for 33 species of butterfly. The data come from the Butterfly Monitoring Scheme and it is unlikely that this indicator could be used for monitoring and evaluation of CS. Although the indicator is “under development” there are still relatively inexpensive and useful ways of indicating the diversity of landscape types and elements within them using an assessment of aerial photographs and/or satellite and/or Lidar images even if landscape functional connectivity cannot be determined.

9.1 Landscape Pattern

Landscape pattern can readily be ascertained from remotely sensed data, either directly or from derived products. Landscape pattern is a requirement to calculate connectivity in the landscape for climate mitigation/adaptation studies (see section 10.4.3).

9.1.1 Direct Methods

Landscape metrics have been developed in several UK and European evaluations of the quality of the landscape for biodiversity, showing diversity of elements and connectivity. Individual farms or matched pairs of farms have often been used and their position in the wider landscape assessed. The size of the block of landscape assessed needs to be considered carefully and is somewhat dependent

[20] River Invertebrate Classification Tool (RICT) and RIVPACS. The Freshwater Biology Association accessed at https://www.fba.org.uk/river-invertebrate-classification-tool-rict-and-rivpacs 14/12/2018

on the size of farms. A block of 3 x 3 1km squares (or 5 x 5 1km squares) may be suitable with the central point of the target farm or agreement option studied in the middle of the block.
High quality digital photographs are preferable but images from Google Earth are usable.

9.1.2 Derived Products

Output from satellite images that have been processed to show vegetation types have been used in the past to determine landscape pattern (e.g. landcover map 2000 and landcover map 2007 which are now out of date) and output from the Sentinel satellite system could be considerably more useful, as it is finer both temporally and spatially, such as the outputs from the National Living Maps project currently underway by Defra & Natural England.

9.1.3 Connectivity (but not functional connectivity)

Aerial photographs have been better at showing linear and small features than satellite derived data in the past but the latest LIDAR and satellite images are remarkably good and a combination of all three will detect most features of interest.

10 Measuring/Evaluating Public Goods

The non-food and fibre public goods/ecosystem services from agriculture considered important to the Government can be assumed from the Agriculture Bill of 2017[21] the list of purposes that the Secretary of State has power to give financial assistance for
(a) managing land or water in a way that protects or improves the environment;
(b) supporting public access to and enjoyment of the countryside, farmland or woodland and better understanding of the environment;
(c) managing land or water in a way that maintains, restores or enhances cultural heritage or natural heritage;
(d) mitigating or adapting to climate change;
(e) preventing, reducing or protecting from environmental hazards;
(f) protecting or improving the health or welfare of livestock;
(g) protecting or improving the health of plants.

In the sections above we have already considered “a” but not the others, ”f” and “g” although relevant to the wider aims of CS and organic farming are targeted more at disease prevention.

10.1 Access to the Countryside

Access provision and enjoyment to and of the countryside that is directly related to the organic options in CS will be rare. However, it should be possible to gauge benefits associated with these factors by comparing organic farms with conventional farms and especially for farms in conversion.
Access provision could be permissive paths and areas but also includes: farm shops, pick-your-own, Open Farm Sunday, lambing days etc.
These factors could be determined by direct observation on a farm visit, through questionnaires or web-searches.

10.2 Rural employment

Organic farming is believed to aid rural employment. Questionnaires could also be used to ask how many staff farms employ directly.

[21] https://publications.parliament.uk/pa/bills/cbill/2017-2019/0292/18292.pdf

10.3 Cultural Heritage

Although a key objective of CS it is difficult to see how organic farming protects cultural heritage unless there is a connection between traditional farming/rare breeds and organic farming that is over and above that associated with conventional farming. Information on rare breeds could be gathered easily when contacting the farmer to arrange visits. Cultural landscape protection will be inferred from information gathered for Section 9 – Landscape.

10.4 Mitigating or adapting to climate change

The degree to which an individual farm is contributing to climate change mitigation and adaptation is not straightforward to measure. Greenhouse gas (GHG) emissions (CO_2, CH_4, N_2O) and soil carbon being the main relevant mitigation parameters, and habitat fragmentation and connectivity for adaptation.

10.4.1 Greenhouse gas emissions

Theoretical values for GHG emissions could be used (Including off site GHG emissions associated with fertiliser manufacture and production of animal feed), and modelled. Alternatively at much greater expense, static chambers could be used in-situ.

10.4.2 Carbon sequestration/storage

The degree to which an individual farm is contributing to carbon sequestration/storage would require a carbon audit of the farm including associated GHG emissions from the manufacture and transport of animal feeds, fertilisers etc. There are measures that could be used to gather information for the whole sample. In particular the number of trees planted and/or protected will give an indication of carbon sequestration following the models of Lamb et al (2016). The measure required for this is the number of new trees and/or area of new trees (actual and planned) to which the model of carbon sequestration will be applied. The area converted from arable to grass or to biomass could also provide some very interesting information for modelling, in addition to soil carbon analysis.

An alternative approach would be to utilise the Land Carbon Management Plan (LCMP) tool to provide a summary of the potential carbon storage achieved by the CS options (Dimambro et al., 2011a).

The methods and results from an ongoing project[22] by the University of Herfordshire that aims to create a tool which estimates the soil carbon sequestration potential of CS and ES options could, if successful, provide the basis on which field methods are developed for the evaluation of CS organic options.

An estimate of ammonia and other nitrogen emissions as well as methane emissions should be estimated in relation to the local APIS figures.

10.4.3 Climate change adaptation

The potential of the landscape to act as a mitigation against or adaptation to climate change can be assessed, based on the information collected from biodiversity and water studies in conjunction with the landscape pattern statistics generated from the methods suggested in Section 9.1.

[22]LM0470 - Establishing a field-based evidence base for the impact of agri-environment options on soil carbon and climate change mitigation
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20017&FromSearch=Y&Publisher=1&SearchText=lm0470&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

Provided the newly trialled CS Baseline climate change assessment method is deemed a success, this method (or elements thereof) could also be included. However, time would need to be added for the desk study element of this (feature inventory and habitat connectivity assessments), which can take a significant length of time, especially for large holdings. As the current method focuses on CS options and habitats, some revisions may be necessary for holdings which have no specific CS options, just organic management or conversion.

10.5 Flood Mitigation

Flood mitigation, if it is considered with organic or conventional options of CS, is related to both climate mitigation and also to the prevention of environmental hazards. The measurements taken for both soil erosion and water quality (Sections 7 and 8) as well as landscape pattern (Section 9.1) will provide the data to determine the impacts of the options on flood mitigation. A key question to answer is whether the water leaving flooded organic farmland is of a different quality to that from conventional farming.

11 Sample Size

11.1 Methods of stratifying the sample

There are many ways that a sample to investigate the organic options of CS could be stratified. The questions to be answered (Section 3.1) require that the sample of agreements/farms (with fields being the unit of sampling) needs to compare farms with maintenance options with conversion options (2 factors).

There also needs to be a comparison with conventional farms in CS with the same or similar options. It would also be useful to compare with existing organic farms and conventional farms not in agri-environment schemes (3 factors).

There are likely to be major differences between arable/horticulture and livestock production (2 factors).

Farm size could be included as a factor (small, medium, large, part of large farm– 4 factors).

These strata give (2x3x2x4) 48 combinations which is already a large number.

11.2 Power analysis

An *a priori* power analysis is a very useful tool when considering what can be achieved with available resources as it indicates the sample sizes required to achieve a statistically useful result. If the effects that are to be tested are expected to be large, for example a 75% decrease in pollutants, then a small sample size should be adequate. However, if the effects are small, for example a change in the Ellenberg fertility index for vegetation by 0.1 units, then the sample size will need to be large to show that effect as statistically significant. The latter is why Countryside Survey has been able to show subtle changes because the sample size was large and also probably why studies on ELS showed no significant changes – the sample size was too small (or, of course, there were no changes to be found).

The software package R has a library "pwr" that allows the calculation of *a priori* levels for sample size, effect size, power and significance. If three of these four elements are available the fourth can be calculated. For example the sample size required for different combinations of effect size and power at <0.05 significance can be easily produced.

A simple table (Table 3) shows the sample size required to show effects of different sizes (0.1 = small, 0.25 = medium, 0.4 = large; as recommended by Cohen, 1992) at different levels of power at a significance of <0.05 in a one-way ANOVA. Table 2 gives examples for 24 groups (e.g. a 6 x 4 experimental design), 16 groups (e.g. a 4 x 4 experimental design), 12 groups (e.g. a 6 x 2 experimental design), 8 groups and 4 groups.

Table 3. The sample size required to achieve a statistical significance of <0.05 for a range effect sizes (0.1 = small, 0.25=medium, 0.4 = large) with a range of power from 0.7 to 0.9.

Power	Effect Size	24 groups - sample size per group	Total sample for 24 groups	16 groups - sample size per group	Total sample for 16 groups	12 groups – sample size per group	Total sample for 12 groups	8 groups - sample size per group	Total sample for 8 groups	4 groups - sample size per group	Total sample for 4 groups
0.7	0.1	78	1872	98	1568	117	1404	148	1184	221	884
0.7	0.25	13	312	16	256	19	228	24	192	36	144
0.7	0.4	6	144	7	112	8	96	10	80	15	60
0.8	0.1	93	2232	118	1888	141	1692	180	1440	274	1096
0.8	0.25	15	360	20	320	23	276	30	240	45	180
0.8	0.4	7	168	8	128	10	120	12	96	18	72
0.9	0.1	115	2760	148	2368	177	2124	229	1832	355	1420
0.9	0.25	19	456	24	384	29	348	37	296	58	232
0.9	0.4	8	192	10	160	12	144	15	120	23	92

Based on previous studies, for many of the elements that are likely to be in a future monitoring scheme, the effects are likely to be small and so to achieve a reasonable level of power at the <0.05 significance level large numbers of farms will need to be surveyed.
It may be possible to achieve a large enough sample size for those variables that can be collected using remote sensing or by volunteer collectors. However, for volunteer collectors there will be some budget required for volunteer recruitment, training and coordination, data collation etc. An alternative approach would be to include farmer self-assessment/monitoring as an agri-environment option although this would not allow monitoring of agreements that have already started. Again, provision of adequate training and support for agreement holders (and potentially their advisors) would be a budgetary requirement (Nugent, 2013).

If the sample sizes required to achieve a likely statistically robust result are too high then an alternative is to use a case-study approach and look in detail at a small number of farms so that descriptive text can be written that can be put into context against national datasets and previously gathered data, much of which was cited in the literature report. This could work well for biodiversity and climate change mitigation but not for soil (physical and biodiversity) because the latter have few data to contextualise the results. The detailed survey would require the collection of data for biodiversity variables (vegetation, birds, bees, earthworms), physical soil variables, soil erosion, water quality habitats and landscape elements. It would also require gathering contextual data from national databases and a detailed farmer interview undertaken by an expert in freeform interviewing techniques and interpretation (rather than a series of fixed questions asked by an ecological surveyor) to gain information on rotations, inputs, carbon budgets, farmer attitudes etc.

11.3 Available data and number of agreements for different options

The number of agreements for each option was previously presented in the report on Existing Data and are repeated here (Table 4). The options where there are not enough examples to provide a sample that could show even large effects with a power of 0.7 (the lowest considered in table 2) statistically are shaded red, those that could show large effects but not medium or small effects are in orange and those that could show large or medium effects but not small effects are in yellow. Options shaded green have enough agreements for a sample to show a small effect.

Table 4. The number of live Countryside Stewardship agreements starting in 2016 or 2017 containing organic options starting in 2016 and 2017. Note that individual farms can have more than one option. Red shading – not enough agreements for a sample to show large effect, orange shading – enough agreements for a sample to show a large effect, yellow shading – enough agreements for a sample to show a medium effect, white – enough agreements for a sample to show a small effect.

Option	Number of live mid-tier agreements	Number of live higher-tier agreements
OR1 - Organic conversion - improved permanent grassland	59	5
OR2 - Organic conversion - unimproved permanent grassland	15	6
OR3 - Organic conversion - rotational land	58	2
OR4 - Organic Conversion - Horticulture	3	
OR5 - Organic Conversion - Top Fruit	2	
OT1 - Organic land management - improved permanent grassland	298	39
OT2 - Organic Land Management - unimproved permanent grassland	109	38
OT3 - Organic Land Management - rotational land	248	31
OT4 - Organic Land Management - Horticulture	21	2
OT5 - Organic Land Management - Top Fruit	7	2
OT6 - Organic Land Management - Enclosed Rough Grazing	7	1

12 Planning the Monitoring and Evaluation

Box 1 is a summary of the information from the literature report and from previous sections of this report. It provides a series of questions that must be answered to allow the monitoring programme to be planned based on the 11 questions in section 3.1. If resources are limited it could be argued that those resources should be spent on gathering data for elements where there is little existing information available on the impacts of organic farming. Consideration should also be given to the likely effect size so that a decision between statistically robust sampling or a detailed case-study approach can be made.

Box 1. Key questions to be answered to enable a monitoring programme to be designed

For which biodiversity elements are existing data/research available to predict the biodiversity impacts of organic farming in CS?

➢ Birds	probably
➢ Vegetation	probably
➢ Bats	no
➢ Bees and butterflies	possibly
➢ Arthropods	yes
➢ Earthworms	no

Which biodiversity elements are required for links to UK biodiversity indicators?

Birds, Bats, Vegetation, Bees and Butterflies

Which biodiversity elements are required to match the CS Baseline Project?

Vegetation, Arthropods, Earthworms, Soil biota

For which other elements are existing data/research available to predict the impacts of CS options?

➢ Soil organic matter	possibly
➢ Soil erosion	no
➢ Soil biota	no
➢ Water quality	no
➢ Habitats/landscape elements	no
➢ Public benefits	no

Note none of these are covered adequately in the CS baseline project.

What is the effect size of CS organic options on each element based on the evidence from the literature review?

Small	bats (unknown), butterflies, arthropods, earthworms (tillage is a large effect), soil biota, water quality (unknown), soil physical properties
Medium	vegetation, bees, soil organic matter, habitats
Large	birds, plants, soil erosion, public benefits (potentially)

12.1 Cost per sample

The costs per sample can be estimated from previous studies (.

Table 5). It should be noted that these are rough estimates that will vary from one organisation to another dependant on the day rates and working practices. The costs do not include training, travel and subsistence.

To show an effect there has to be at least two visits, once to determine the baseline and one to detect changes. We assume there will be a visit in year one of the agreement and one in year five.

An Excel workbook is provided (combining tables 1 to 4) to allow the customer to vary: the biodiversity, soil, water and public benefits elements to include; the statistical power and test effect required to give a sample size. The sample size and elements can be selected in a worksheet "answer" that will give the cost of collecting those variables for the sample size selected.

Table 5. Estimated costs per CS option from one sample based on experience from previous studies

Variable	Method	Equipment cost	Cost per sample site
Habitats (including hedges, individual trees, ponds etc) of surrounding 1km square	By drone and interpretation	1500	£700
Travel to site (time and mileage)	to be shared among vegetation, and soil		£240
Vegetation	Quadrats		£120
	Flower abundance		£120
	Seed abundance		£120
Birds (volunteer survey)	Self-audit by farmers, processing by professionals		£60
Birds (professional survey)	visits in winter and summer		£720
Bats	Norfolk Bat Survey approach (equipment and data processing). Journey to drop-off equipment and to collect	£500 per set	£300
Bees (volunteer survey)	Volunteers, processing by professionals		£60
Bees	Professionals	four visits (share of travel in cell D3 and three separate visits)	£960
Butterflies	included with bees		
Spiders and other arthropods	setting out and collecting traps	£20 per sample site	£240
Spiders and other arthropods	sorting pitfall traps		£300
Earthworms	collecting samples	£10 per sample site	£60
Earthworms	sorting samples		£120
Soil biota	collecting samples	£5 per sample site	£60
Soil biota	sorting samples		£300
Soil biota	bar coding and meta bar coding		£417
Soil Analysis	collecting samples	£15 per sample site	£60
Soil Analysis	pH, Soil carbon, metals etc		£50
Soil Erosion	Estimating probability of erosion per catchment	depends on EA	£100
Soil Erosion	Checking for erosion after storms		£115
Water Quality	RIVPACS - sampling including journey time	£22 per set	£360
Water Quality	sorting		£300
Water quality field assessment	porous cups placed out and collected in winter fortnightly	100 per set	£1,000
Landscape elements	analysis of aerial photos		£60
Carbon sequestration	modelling	3000	£60
Farmer interview	travel, expert interviewer, interpretation		£500
Case Study Review			£750
Total per site (volunteer surveys)		£150	£6,572
Total per site (professional surveys)			£8,132
Fixed cost		£5,000	

13 References

Cohen, J., 1988. Statistical power analysis for the behavioural sciences.

Cohen, J., 1992. A power primer. *Psychological bulletin*, *112*(1), p.155.

Defra 2018b. Organic farming statistics 2017. In., pp. 12.

Dimambro, M., Steiner, J. & Lillywhite, R. 2011a. Land Carbon Management. Options and incentives and how to create your Land Carbon Management Plan. In.

Lamb, A, Green, R., Bateman, I., Broadmeadow, M., Bruce, T. Burney, J., Carey, P., Chadwick, D., Crane, E., Field, R., Goulding, K., Griffiths, H., Hastings, A. Kasoar, T., Kindred, D., Phelan, B., Pickett, J., Smith, P., Wall, E,. zu Ermgasson, E., Balmford, A. (2016). The potential for land sparing to offset greenhouse gas emissions from agriculture. *Nature Climate Change*, **DOI: 10.1038/NCLIMATE2910**

Willer, H. & Lernoud, J. 2016. *The world of organic agriculture. Statistics and emerging trends 2016,* Research Institute of Organic Agriculture FiBL and IFOAM Organics International.

Appendix 1. Power Analyses

ANOVA

Power	Effect Size	24 groups - sample size per group	Total sample for 24 groups	16 groups - sample size per group	Total sample for 16 groups	12 groups – sample size per group	Total sample for 12 groups	8 groups - sample size per group	Total sample for 8 groups	4 groups - sample size per group	Total sample for 4 groups
0.7	0.1	78	1872	98	1568	117	1404	148	1184	221	884
0.7	0.25	13	312	16	256	19	228	24	192	36	144
0.7	0.4	6	144	7	112	8	96	10	80	15	60
0.8	0.1	93	2232	118	1888	141	1692	180	1440	274	1096
0.8	0.25	15	360	20	320	23	276	30	240	45	180
0.8	0.4	7	168	8	128	10	120	12	96	18	72
0.9	0.1	115	2760	148	2368	177	2124	229	1832	355	1420
0.9	0.25	19	456	24	384	29	348	37	296	58	232
0.9	0.4	8	192	10	160	12	144	15	120	23	92

Cohen 1988 suggests that a large effect can be assumed for F = 0.4, a medium effect for F=0.25 and a small effect for F=0.1.

Chi Square

Power	Effect Size	Number required if df=23	Number required if df=15	Number required if df=7	Number required if df=3	Number required if df=1
0.7	0.1	1850	1563	1177	879	617
0.7	0.3	206	174	131	98	69
0.7	0.5	74	63	47	35	25
0.8	0.1	2212	1881	1435	1090	785
0.8	0.3	246	209	159	121	87
0.8	0.5	88	75	57	44	31
0.9	0.1	2750	2358	1828	1417	1051
0.9	0.3	306	262	203	157	117
0.9	0.5	110	94	73	57	42

Cohen 1988 suggest that a large effect can be assumed for Chi-sq of 0.5, a medium effect for Chi-sq of 0.3 and a small effect for Chi-sq of 0.1.

Power Tables for Effect Size d

(from Cohen 1988, pg. 55)

two-tailed $\alpha = .05$ or one-tailed $\alpha = .025$

	d										
Power	**.10**	**.20**	**.30**	**.40**	**.50**	**.60**	**.70**	**.80**	**1.0**	**1.20**	**1.40**
.25	332	84	38	22	14	10	8	6	5	4	3
.50	769	193	86	49	32	22	17	13	9	7	5
.60	981	246	110	62	40	28	21	16	11	8	6
2/3	1144	287	128	73	47	33	24	19	12	9	7
.70	1235	310	138	78	50	35	26	20	13	10	7
.75	1389	348	155	88	57	40	29	23	15	11	8
.80	1571	393	175	99	64	45	33	26	17	12	9
.85	1797	450	201	113	73	51	38	29	19	14	10
.90	2102	526	234	132	85	59	44	34	22	16	12
.95	2600	651	290	163	105	73	54	42	37	19	14
.99	3675	920	409	231	148	103	76	58	38	27	20

two-tailed $\alpha = .01$ or one-tailed $\alpha = .005$

	d										
Power	**.10**	**.20**	**.30**	**.40**	**.50**	**.60**	**.70**	**.80**	**1.0**	**1.20**	**1.40**
.25	725	183	.82	47	31	22	17	13	9	7	6
.50	1329	333	149	85	55	39	29	22	15	11	9
.60	1603	402	180	102	66	46	34	27	18	13	10
2/3	1810	454	203	115	74	52	39	30	20	14	11
.70	1924	482	215	122	79	55	41	32	21	15	12
.75	2108	528	236	134	86	60	45	35	23	17	13
.80	2338	586	259	148	95	67	49	38	25	18	14
.85	2611	654	292	165	106	74	55	43	28	20	15
.90	2978	746	332	188	120	84	62	48	31	22	17
.95	3564	892	398	224	144	101	74	57	37	26	20
.99	4808	1203	536	302	194	136	100	77	50	35	26

Table values represent the number of participants *per condition* (n) needed to obtain a significant result at the given alpha, for that effect size, and power level.

Example: Previous research suggests the given effect size estimate between the experimental and control conditions is d=1.0 (one standard deviation apart). To design a study at the recommended level of 80% power, how many participants do I need?

for two-tailed $\alpha = .05$, d=1.0, and Power=.80.......n = 17 (N = 34 for Between Groups)
(N = 17 for Within Groups)